An Integrated Systems Engineering Toolset for Performing Life Cycle Cost Tradeoffs

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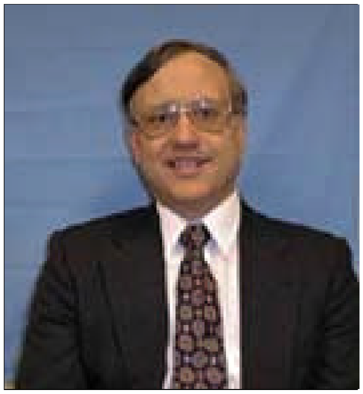

Mr. Barnett is a Principal Member of the Engineering Staff at Lockheed Martin's Advanced Technology Laboratories in Camden, NJ. He has led the development effort for an integrated system engineering toolset, developed radar system concepts, and has refined and implemented algorithms on embedded signal processors. He was a radar systems engineer at Lockheed Martin's Ocean and Radar Sensor Systems in Syracuse, NY prior to his current position.

ABSTRACT

Technology improvements are leading to complex systems, which allow the warfighter to perform more effectively. New computer aided engineering (CAE) tools and methods are needed by designers to optimize these complicated systems. This paper focuses on the development of an emerging integrated system engineering toolset that forms the basis for a concurrent engineering design environment. This integrated toolset, which consists of Ascent Logic's RDD-100, Price Systems' cost estimating tools and Management Sciences' RAM-ILS toolset, provides the design team with the capability of estimating life cycle costs and reliability for electronic systems early in the design process. Although this toolset is relatively immature, various companies are starting to use these integrated tools in performing CAIV (Cost As an Independent Variable) tradeoffs for new DoD systems.

INTRODUCTION

Techological advances are leading to complicated systems which allow the warfighter to perform more effectively. However, these systems are becoming so complex that our ability to design them cost-effectively is extremely difficult with current practices. As a result, new design methodologies, infrastructure and computer aided engineering (CAE) tools are required to design the types of systems the warfighter needs to maintain a tactical advantage over the enemy.

Lockheed Martin's Advanced Technology Laboratories (ATL) was one of the two prime contractors for the recently concluded DARPA/Tri-Service-sponsored Rapid Prototyping of Application Specific Processors (RASSP) program. The goal of this program is to reduce the development and manufacturing time and the life cycle costs of embedded signal processors by a factor of four. ATL identified the following areas as major factors in achieving the required improvement:

- Hardware/software co-design methodology and virtual prototyping technology are needed to ensure first pass design success.
- Model year architecture approach which enables design reuse and easy technology upgrades must be used.
- An enterprise infrastructure, which increases engineering productivity, is required.
- Life-cycle cost trade-offs early in the design process are critical in optimizing the system.

As a part of the RASSP program, an integrated systems engineering toolset was developed which forms the basis for a concurrent engineering environment. This design environment consists of Ascent Logic's RDD-100, Price Systems' parametric cost estimation models and Management Sciences' RAM-ILS toolset. This design environment provides the integrated product development team (IPDT) with the capability to estimate the life cycle costs and reliability of the system early in the design process. This paper describes the integrated systems engineering toolset, benefits of using this toolset, an application example which illustrates the advantages of using these tools and a description of how this toolset is evolving in the marketplace.

INTEGRATED SYSTEM TOOL DESCRIPTION

Systems engineering decisions early in a project significantly impact schedule and cost. Decisions are typically based on the impact to the current phase of a project, rather than the project's overall life cycle. Decisions made during the conceptual system design phase typically determine the total costs incurred over the entire life cycle. To help the integrated product development team (IPDT) make these trade-offs, a concurrent engineering environment consisting of Ascent Logic Corporation's (ALC) RDD-100 tool with PRICE Systems parametric cost estimation models and Management Sciences' (MSI) RAM-ILS tool set was developed on the RASSP program, as shown in Figure 1. Design information is passed among these tools in this concurrent engineering environment to provide design, cost, reliability, availability, and maintainability support to the IPDT.

This concurrent engineering environment provides the IPDT with the information they need to make decisions early, while making changes is still easy and inexpensive. This environment will allow engineers to make decisions based not only on the current effect of a change, but on the predicted long-term impacts. This information is essential to significantly reducing life-cycle costs.

The capabilities for each of the individual tools and for the integrated toolset are described next.

RDD-100. The ATL RASSP team selected Ascent Logic Corporation's RDD-100 tool as the central tool of its integrated toolset. This tool provides requirements analysis, functional analysis, and physical decomposition capabilities. It is an Entity, Relationship, Attribute (ERA) database tool with a substantial graphical data entry user interface.

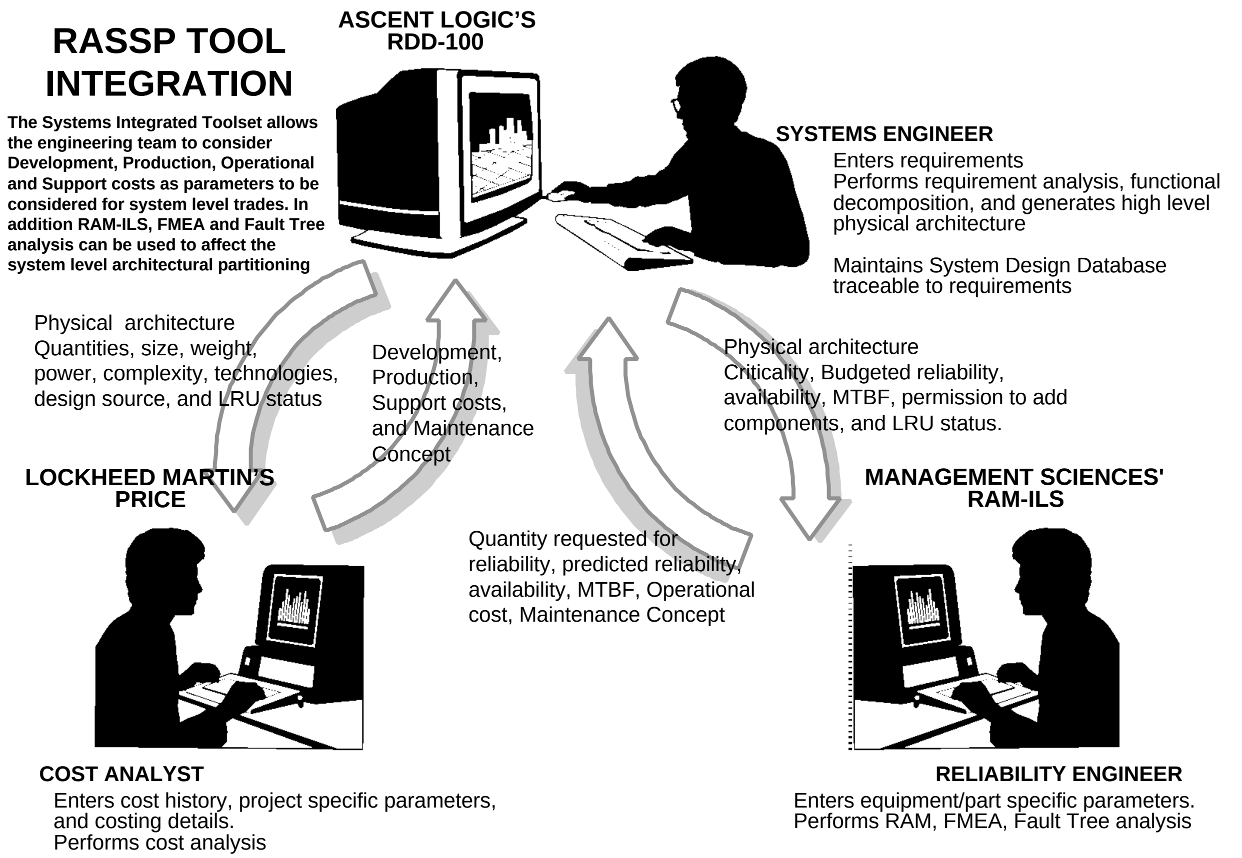

Figure 1 Concurrent Engineering Environment

RDD-100's database capability enables it to be the primary data storage tool for the tool set. The ATL RASSP Team defined a set database extensions that support the IPDT through the life of a project.

The RDD-100 tool provides the IPDT with three different views of a system: a requirements view, a functional view, and a physical view. The requirements can be related to the functions and the functions can be allocated to the physical architecture. The interrelation of these three views enables users to automatically generate the lower specification documents from the RDD-100 database. The physical view enables cost analysis and reliability and maintainability analyses.

PRICE Systems Cost Estimation Models. The ATL RASSP team selected PRICE Systems' parametric cost estimation models as the cost analysis tool. These models were originally intended to be used by a cost analyst. PRICE Systems modified them to allow access to the PRICE models through parameters contained within the RDD-100 database and to provide costing information back to this database. The PRICE Systems' tools include a set of four parametric cost estimation models, each with a different specialty areas. Three of the models focus on hardware costing and the fourth model focuses on software costing. These models are summarized below:

- PRICE H: This model specifically addresses the costs associated with development and production of hardware. This tool can use outputs of the PRICE M tool.
- PRICE HL: This model uses data generated by PRICE H and calculates the hardware life-cycle costs, including sparing for a deployment environment.
- PRICE M: This model specifically addresses electronic-module-level hardware development and production costs. It allows engineers to specify individual ASIC and FPGA components to get a detailed cost estimate at the lowest levels.
- Software: This model estimates both development costs and life-cycle support costs for software.

The PRICE models are based on historical models and can be calibrated to match any company's process. These models have been used to achieve cost estimates within five percent of actual costs.

Reliability, Availability, Maintainability: Integrated Logistics Support (RAM-ILS). Management Sciences' RAM-ILS tools calculate reliability, maintainability, and availability of a system. This toolset performs mean time between failure (MTBF) and availability calculations using several methods, including Mil-Hdbk-217 and BelCore. If the system doesn't meet the MTBF requirements, RAM-ILS will perform a cost driven trade-off and recommend where redundancy can be added to effectively meet the system MTBF requirement. RAM-ILS is integrated with the Mentor Falcon Framework, which allows it to access the detailed design database to continually improve its estimates as the detailed design progresses.

Integrated Tools. The ATL RASSP team has developed a concurrent engineering environment based upon COTS tools which supports the RASSP systems engineering process. This concurrent engineering environment, which is shown in Figure 2, consists of Ascent Logic Corporation's (ALC) RDD-100 system engineering tool, Lockheed Martin PRICE Systems cost estimation tools and Management Sciences' (MSI) RAM-ILS toolset. RDD-100 is used to capture and analyze the requirements, to define the functional behavior of the system, to allocate the requirements and functions to the subsystems, and to provide requirements traceability. PRICE cost estimating tools are used to estimate the development, production and support costs for the processing system. The RAM-ILS tool is used to perform reliability and maintainability analyses.

Each tool passes data to another tool through an ASCI file with the appropriate format. The types of data, which are passed from one tool to another, consist of the data that typically resides in that tool and can be used by the other tool. For example, system engineering data is passed from RDD-100 to the PRICE cost estimating tool. This approach eliminated the need for implementing a GUI interface for PRICE and RAM-ILS in the RDD-100 tool. The types of parameters, which are passed from RDD-100 to PRICE, include the equipment configuration, size, weight, power, technology and complexity factors. The development, production and support costs are calculated within the PRICE tool and these costs are back annotated into the RDD-100 database. On the other side of the interface, the equipment configuration, allocated reliability and maintainability budgets, and cost data are passed from RDD-100 to the RAM-ILS toolset. The reliability and maintainability assessment is performed within the MSI toolset and the results of these analyses are back annotated into the RDD-100 database. In addition, optimizations can be performed within the RAM-ILS toolset when the reliability requirements are not met and the tool can make a recommendation on how redundancy can be

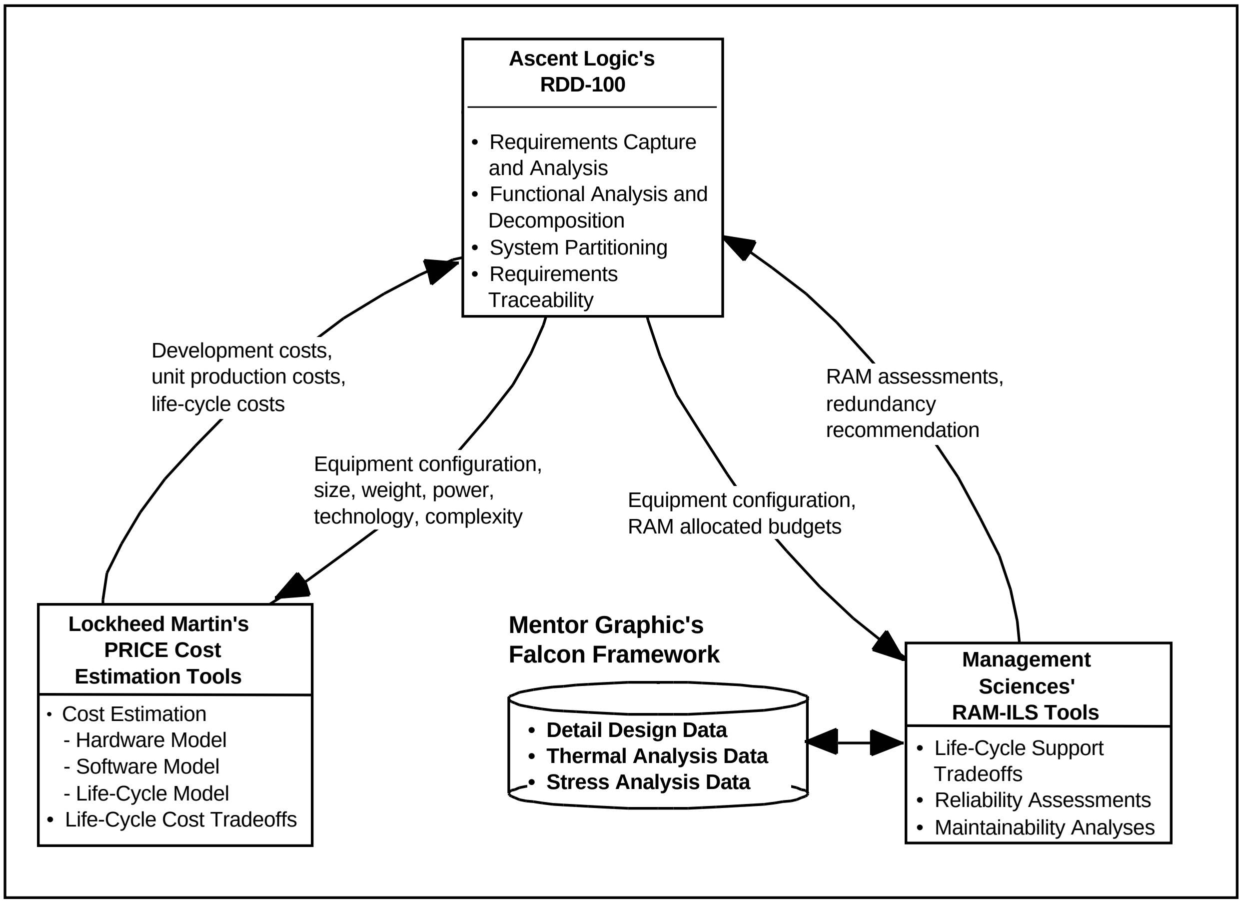

Figure 2: Integrated Systems Engineering Toolset

added in the system in the most cost-effective way to meet the requirements.

BENEFITS OF USING THE INTEGRATED SYSTEMS ENGINEERING TOOLSET

The integrated system tools provide a concurrent engineering environment where tradeoffs considering a product's complete life cycle are performed. Multi-disciplinary design data is stored in one location that the entire IPDT team can assess. As a result, the entire design team uses the same data within their analyses, which eliminates the confusion when parameters are maintained in multiple locations. Cost performance tradeoffs are performed using the integrated tools to optimize the system design over multiple disciplines. The integrated tools provide a quick impact analysis capability, as detailed design data can be used to update the reliability and cost predictions.

The integrated system tools provide an efficient process for the engineer to access cost data. Engineers can obtain complete life cycle costs using the system tools without becoming an expert cost analyst. The integrated system tools provide an environment, which can be effectively used to implement either Design To Cost (DTC) or Cost As an Independent Variable (CAIV) programs, which are being emphasized within DoD. The cost estimation process has been established so the cost analyst is able to control the estimate.

The integrated system tools provide a reliability and maintainability analysis capability throughout the design process. These tools provide the mechanism that allows specialty engineers to be involved early in the design process. The RAM-ILS tool provides capabilities to perform reliability, maintainability, success tree and FMECA analyses. In addition, the system architecture can be optimized to meet reliability requirements in a cost-effective fashion with the integrated system tools.

APPLICATION EXAMPLE

The ATL RASSP team performed a trade-off between two architecture candidates for a synthetic aperture radar (SAR) signal processor application using the integrated system tools. Requirements and functional analysis for this application was performed to determine the hardware and software needed by each candidate architecture to satisfy the requirements. The first candidate architecture uses mature signal processing technology, while the second architecture uses state-of-the-art processors. This tradeoff is difficult because a mature technology is less expensive per module and is lower risk, while the state-of-the-art technology needs fewer modules, is more compact and consumes less power.

The physical decomposition is the only information required for performing cost and reliability analysis. The team developed an equipment tree structure containing the software and hardware elements for both candidates. The following information is populated in the RDD-100 database for each component in each architecture candidate: component type, component subtype, quantity in next higher level assembly, quantity required for operation, redundancy mode, length, width, depth, weight, power, technology, technology maturity and design source.

A cost estimate for both architectures was calculated using the PRICE H, PRICE HL and PRICE S tools. Component data from the RDD-100 database was exported into a text file, which was used to import this data into the PRICE tools. Development, production and support costs were calculated for 500 production units with a 20-year life cycle. These costs for both architecture candidates were back annotated into the RDD-100 database. This process of exporting data from RDD-100 to PRICE, calculating the costs and back annotating the cost data in RDD-100 was completed within minutes. This quick response time enables the IPDT to examine a large number of candidate architectures in a short amount of time.

In a similar fashion, component data and allocated requirements are exported from the RDD-100 database and imported in the RAM-ILS toolset. The RAM-ILS toolset was then used by the IPDT to determine the overall reliability for the system for both architecture candidates. One of the architecture candidates did not meet the overall system reliability requirement. The RAM-ILS tool was then used to perform a trade-off to determine the most cost-effective approach to add redundancy to the system to meet the overall reliability requirements.

This process of characterizing the components for a candidate architecture within RDD-100 and passing this data to the PRICE and RAM-ILS toolset to perform cost and reliability estimates continued in an iterative fashion until all requirements are met. The results for the trade-off between the mature (Candidate 1) and state-of-the-art processing (Candidate 2) technology for the SAR application are given in Table 1.

Table 1 Trade-Off Table

Cost Type	Candidate 1 ($M)	Candidate 2 ($M)
Development Cost	2.0	2.1
Production Cost	101.0	89.1
Life Cycle Support Cost	39.6	29.8
Total Cost	142.5	113.0
MTBCF (Mean Time Between Critical Failure)	2607 hours (Redundancy Required)	3296 hours (No Redundancy)

During a typical project, the development cost is primary criterion used to select the best architecture. As a result, the architecture with the lowest life cycle cost may not be selected. With the integrated system tools, the IPDT can pick the most cost-effective solution based upon total life cycle costs. In the past, the architecture based upon mature technology (Candidate 1) would have been typically selected because there was no easy process to determine life cycle costs. It is clear from this application example that Candidate 2 is the better solution because its life cycle costs are lower and this candidate is more reliable.

EVOLVING INTEGRATED SYSTEM TOOLS

A prototype of the integrated system tools was developed for the RASSP program and was demonstrated in the first quarter of 1997. The productization of the enhancements to each of these three CAE tools is the responsibility for each of the software vendors. Ascent Logic, PRICE Systems and Management Sciences continue to evolve the integrated capabilities of their respective tools based upon market conditions. Ascent Logic and PRICE Systems have commercialized the interface between their respective tools. This integration is offered as a part of their standard commercial product. Ascent Logic and Management Sciences have not yet seen enough of a market demand to commercialize the interface between their tools.

The integrated system toolset was optimized for signal processing applications on the RASSP program. Ascent Logic and PRICE Systems are extending the capabilities of their integrated tools for operation in other domains such as ship electronics, airborne electronics and structural and mechanical systems. Various companies throughout the aerospace industry are evaluating the RDD-100 and PRICE integration for performing CAIV (Cost As an Independent Variable) trade-offs for upcoming DoD applications.

The basic feasibility of using these integrated tools was demonstrated on the RASSP program. It is anticipated that other software vendors of competing tools will develop the appropriate interfaces to provide similar capabilities as the RASSP integrated system tools. The capabilities provided by the integration of system engineering, cost estimation and specialty engineering tools will become more robust and widely accepted as more users apply these tools to different domains. Eventually, the capabilities provided by these integrated tools will become a part of standard practice.

SUMMARY

As a part of the RASSP program, the ATL team developed a concurrent engineering environment consisting of three existing CAE tools (RDD-100, PRICE cost estimating tools, and RAM-ILS). This system design environment quickly provides more detailed and accurate information to the IPDT, and enables them to make better-informed decisions early in a system's life cycle. Since these early decisions have the largest impact on the overall life-cycle costs of a system, it is important that these decisions are based upon total life cycle costs and not just the initial development costs.

As shown in the application example, it is possible to select the wrong architecture if the decision is only based upon development costs. The life-cycle costs are reduced by over 20 percent by understanding these costs early in the design process for the example presented. This information is critical in designing affordable systems in the future.

Although these integrated tools were initially developed for signal processing applications, they can be extended to work for other application domains. Ascent Logic and PRICE Systems have commercialized the integration between their respective tools and are enhancing this integration to work for other domains. Even though the integration among these tools is still relatively immature, various aerospace companies are evaluating these products for performing CAIV trade-offs for upcoming DoD programs. Eventually, the capabilities provided by these integrated tools will become a part of standard practice.

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VENDOR WEB SITES

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